**Solar and Heliospheric Physics**
**Abstracts of selected proposals.**
**(NNH05ZDA001N-SHP)**

Below are the abstracts of proposals selected for funding for the Solar and Heliospheric Physics Program. Principal Investigator (PI) name, institution, and proposal title are also included.

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**Peter Beiersdorfer / University of California at Berkeley**
**A New Look at the Solar EUV Emission in the 20 to 200 Å Region**

Accurate and complete knowledge of the spectral emission from the dominant heavy ions found in the solar corona, transition region, and photosphere is crucial for describing the solar EUV emission. Our understanding of this emission is, however, neither accurate nor complete. Work on understanding the EUV spectra from cool stars, such as alpha Cen, has shown that the spectral models used to describe radiation in the 20 - 180 Å region are very incomplete. Laboratory measurements of such ions as Fe IX, X, XI, and XII have shown that the emission below 140 Å may be underestimated by existing spectral models by as much as factors of three to four. Similarly, more than half of the lines recorded in spectra available from the Sun has not yet been identified! Not knowing which elements and which ionization stages are responsible for the solar emission in this region limits our ability to understand and model the solar energy flow in this region of the electromagnetic spectrum and its effect on Earth and the space environmental conditions. By contrast, nearly complete sets of laboratory data of Ne, Mg, Al, Si, S, Ar, Ca, Fe, and Ni are now available that we can use to establish line lists and line intensities of the relevant ions found in the Sun. We are proposing to use these data in conjunction with new calculational tools to establish complete descriptions of the solar EUV radiation in the 20 - 200 Å region and thus to close the glaring gap in our understanding of the electromagnetic spectrum emitted by the Sun. Very importantly, we will make a careful estimate of the multitude of weak, blended transitions that have recently been shown to form a quasi-continuum and have generally been ignored in the literature. We will apply our spectral emission data to the analysis of existing solar EUV spectra, such as those obtained from the Atmosphere Explorer-E satellite and Aerobee Rocket observations. The aim is to identify the wealth of features and lines that have been observed in this wavelength band but have never been assigned to specific ions or transitions and to assess their role in the overall energy flux in the 20-200 Å wavelength band.

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**Jeffrey Brosius / The Catholic University of America**
**Dynamics of Solar Transient Phenomena Based on High Time Resolution EUV Spectra**

An existing, extensive database of rapid cadence (9.8 sec) spatially resolved EUV slit spectra of solar transient phenomena (including flares, nanoflares, and blinkers) obtained with CDS during the past six years of SOHO operations will be analyzed and interpreted, along with coordinated observations from other NASA instruments. This unique database represents a nearly untapped resource for analyzing and understanding solar transients. Observed EUV emission lines cover a wide range of temperature from the chromosphere (He I) through the transition region (He II, O III, O IV, O V, Ne VI, Ca X) to the corona (Mg X, Al XI, Si XII), and include hot flare emission (Fe XIX). Profile fits to emission lines in the slit spectra yield the integrated intensity, centroid wavelength, and width, from which EUV light curves, relative Doppler velocities, and nonthermal turbulent velocities will be calculated, all in high time resolution. This reveals the time dependent response of the solar atmosphere (over a wide temperature range) to the observed transient phenomena, and provides new insight into physical processes that occur during solar transients. For example, the measurement of simultaneous, cospatial mass flows in lines formed at different temperatures will provide new information regarding momentum balance during chromospheric evaporation. Light curves and velocity histories of nanoflares will reveal if nanoflares are miniature versions of regular flares. Time-dependent transition region densities within the various transient phenomena will be derived from the density sensitive ratio of O IV lines, and time-dependent temperature distributions of emitting plasma (the differential emission measure DEM) will be constructed for selected events. Two-dimensional imagery associated with each transient event observed with CDS will be obtained with SOHO's EIT. These will be used to fine-tune the CDS pointing coordinates, and establish the context within which the CDS spectra were obtained. Associated two-dimensional imagery obtained with TRACE will be used for cases in which more rapid cadence context imagery is available. Magnetograms from SOHO's MDI will be used to not only associate the EUV transients with specific magnetic features, but also to establish whether the transients are associated with changes in those magnetic features. Images from RHESSI will reveal the locations of hard X-ray sources relative to observed EUV transients. Hard X-ray spectra and light curves will be examined at the locations of EUV transients. Relative timings between the onsets and peaks of the thermal and nonthermal hard X-ray emission, combined with the onsets and peaks of the (thermal) EUV emission, will provide information on the dominant mechanism(s) by which flare (and nanoflare) energy is transported to the chromosphere (e.g., particle beam, thermal conduction). Coordinated hard X-ray observations from Yohkoh will be employed for older events. This investigation addresses the fifth National Objective of NASA's Strategic Objectives, namely, to “Study the Earth system from space and develop new space-based and related capabilities for this purpose." It will focus primarily on the second NASA Objective of this fifth National Objective by exploring the “Sun-Earth system to understand the Sun and its effects on Earth, the Solar System, and the space environmental conditions that will be experienced by human explorers."

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**Nicholas Brummell / University of Colorado**
**Dynamics of the Solar Tachocline: The Creation and Evolution of Buoyant Magnetic Structures**

The current paradigm for the operation of the solar magnetic cycle relates the surface magnetic activity to the emergence of a strong toroidal magnetic field from below. It is believed that this strong toroidal field is likely generated from weak seed poloidal field by the inductive stretching action of strong localised velocity shear in the solar tachocline, a region bridging the mismatched velocity profiles of the differentially-rotating convection zone and the solid-body rotating inner radiative zone. It is further believed that the induced field somehow generates strong toroidal magnetic structures that rise by magnetic buoyancy through the solar convection zone to emerge as active regions. We propose to continue our investigations of the fully nonlinear mechanisms involved in these processes via numerical simulations of the full MHD equations and supportive analytical work. We will continue our studies of the ability of velocity shear interacting with magnetic field to create buoyant magnetic structures, both directly as "tubes" and via instabilities of magnetic layers in the presence of shear. From earlier studies, we have already found that magnetic structures can indeed be created from seed field via shear and magnetic buoyancy mechanisms in various configurations. These structures may visually resemble our notion of an idealised,isolated magnetic "flux tube" but in reality are dynamically substantially different. We intend to investigate the generation and long-time evolution of such non-idealised structures further, in order to assess their relationship to idealised tubes and to categorise their intrinsic properties. We will also extend our analyses of this system's remarkable ability to operate as a dynamo complete with cyclic behaviour, polarity reversals and periods of inactivity. In particular, we will test the influence of background turbulence on the dynamo efficiency. We will subsequently examine the requirements demanded for these more realistic structures to rise successfully through a convective background to appear like active regions, or the processes involved in their destruction and possible recycling as poloidal field ("alpha-effect"-like mechanisms) both in the presence of rotation and without. We will design and extract observable characteristics, such as the strengths and geometries of the structures and especially any helical content, so that a comparison with solar observation data (such as that from SOHO, TRACE, STEREO, Ulysses and the forthcoming SDO mission) may reveal insight into the dynamics in the solar interior.

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**Cynthia Cattell / University of Minnesota**
**Microphysics of Interplanetary Shocks**

The role of microphysical processes in the structure and dynamics of collisionless shocks has long been of interest, in space and astrophysical plasmas and in basic plasma physics. Interplanetary shocks play an important role in modulating the structure and dynamics of the heliosphere and are associated with acceleration of energetic particles, including gradual SEP events. Near 1 AU, most interplanetary shocks are associated with coronal mass ejections (CMEs). Because of their role in energization of particles and in modulating transport, a detailed understanding of the microphysics of shocks is critical to characterizing and, ultimately, predicting the "space environmental conditions that will be experienced by human [and robotic] explorers" (NASA Sun-Solar System 2005 Roadmap) in the heliosphere. The shock ramp region contains strong currents, and often other sources of free energy such as ion and/or electron beams. Wave growth due to these free energy sources often leads to very large amplitudes, and nonlinear electric field structures are observed. Recent PIC simulations of magnetosonic shocks have shown that electron phase space holes develop in the ramp region and result in electron scattering and energization, as well as modification of the ion distributions. Understanding this type of nonlinear structure requires time-domain measurements of the electric field waveform as are provided by the Wind Waves TDS. However, to our knowledge, there have been no studies of time domain waveform capture data to reveal in detail the microphysics of interplanetary shocks near 1 AU. Our pilot study, described below, has revealed a rich and highly variable phenomenology. We propose to use an existing database of interplanetary shocks observed by Wind to perform a statistical study of detailed study of the microphysics of shocks and waves upstream and downstream of the shocks. In addition, the data sets from the magnetometer and several plasma instruments will be utilized. The proposed work will help to provide the fundamental physics understanding of interplanetary shocks that will be required to ultimately obtain a predictive capability for interplanetary shock evolution and dynamics and the associated particle energization. The Wind/Waves TDS provides a unique data set for the study of microphysics of interplanetary shocks. The primary goal of the proposed research is to perform an in-depth observational study to characterize the waves and micro-scale structures associated with fast mode interplanetary shocks observed by the Wind satellite and to compare the satellite observations to simulations that address the role of microphysics in the dynamics of shocks and energization of particles. This research is enabled by developments in both satellite instrumentation (high time resolution "burst mode" electric field measurements with large dynamic range) and in computers, allowing particle-in-cell simulations to follow electron dynamics and structures on electron scales (rather than just hybrid or MHD simulations) of these physical processes. Our team has the experience in analysis of shocks, time-domain electric field and wave data and in comparisons of observations and simulations to obtain closure on the proposed questions.

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**John Davis / NASA Marshall Space Flight Center**
**Measuring Upper Chromosphere and Transition Region Magnetic Fields: An Experimental Investigation**

This proposal is based on the premise that to understand the fundamental processes that lead to the explosive release of magnetic energy in solar flares and CMEs it is necessary to understand the topology and evolution of the magnetic field in the region where the magnetic field dominates. Achieving this goal requires the measurement of the vector magnetic field over a range of heights and temperatures in the solar atmosphere from the photosphere to where the field becomes force free. We have developed a sounding rocket vacuum ultraviolet spectropolarimeter that will measure the polarization states of two upper chromospheric/ lower transition region emission lines, MgII and CIV, which are potential candidates for the upper range. The payload incorporates several new technologies, including a multilayer coated "cold mirror" primary, a MgF2 double Wollaston polarization analyzer and a pair of toroidal variable line spaced gratings. In conjunction with the instrument development, one of the Co-Investigators is undertaking theoretical studies that will enable the derivation of the magnetic field from the Stokes line profiles. By the end of FY06 the payload is expected to be complete and ready for final test, calibration and flight. A launch date in the early summer of 2007 is proposed in order to coordinate our observations with Solar-B and to obtain the highest solar elevation at the launch site to maximize the observing time for CIV. If, as we expect, the program demonstrates that the magnetic field in this region can be measured using these lines, this will demonstrate the feasibility of an orbital instrument that can study the evolution of the magnetic topology leading to magnetic eruptions and lay the foundation for forecasting the occurrence and magnitude of solar energetic particle events.

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**Holly Gilbert / Rice University**
**The Evolution of Prominence Mass and its Relation to Coronal Mass Ejections**

Prominences have long been associated with coronal mass ejections (CMEs) and provide an important component in our understanding of the

Sun-Earth system as a whole. Although some prominences are long-lived and others erupt or disappear on short time scales, all types of prominences are dynamical and many show mass loss in observations through draining. There are several different potential mechanisms involved in causing such mass loss. The proposed work, motivated by the close connection between prominences and coronal mass ejections (CMEs), offers a detailed study of the variation in mass of various types of prominences by addressing four mechanisms involved in mass loss: draining along field lines, reconnection, cross-field diffusion, and MHD instabilities. The prominences in this study will range from those that lift and settle (sometimes called a failed or frustrated eruption), to those that exhibit a partial prominence eruption, to those that have a complete prominence eruption. Included in this study of prominence flows and concomitant mass variations will be a range of CMEs that exhibit the various types of eruptive prominence behavior. A search for a relationship between the nature of a prominence eruption and the pre-eruption flow patterns will be conducted as well as an examination of the basic CME properties (e.g., speed, mass, and energy) that are associated with the different types of prominence eruption.

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**Shadia Habbal /University of Hawaii, Institute for Astronomy**
**Large Scale and Fine Scale Density Structures of the Quiescent and Dynamic Solar Corona**

This proposal seeks to explore the underlying properties of the quiescent and dynamic nature of the large and fine scale structures of the corona for conditions typical of solar minimum and maximum. With the coronal magnetic field continuing to elude known measurement techniques, density structures observed in white light measurements of the corona remain the most plausible proxy for the configuration of the coronal magnetic field. This configuration forms the basis for modeling efforts of the corona and solar wind, which serve as an experimental tool for investigating physical processes responsible for coronal heating and solar wind acceleration. Coronal density structures also serve as a context for the interpretation of in situ solar wind measurements, and for establishing the source of different solar wind streams at the Sun. The starting point for this three year program will be the use of a newly developed image processing tool that reliably reveals the fine scale structures in the quiescent and dynamic corona, down to the limit of the spatial resolution of the instruments, without introducing any artifacts. By combining ground-based measurements of polarized brightness from Mauna Loa and the Large Angle and Spectrometric Coronagraph (LASCO/C2), observations from the Extreme ultraviolet Imaging Telescope (EIT) and the Ultraviolet Coronagraph Spectrometer (UVCS), the utility of existing SoHO data, covering a full solar cycle, will be exploited for studies of: - the source at the Sun of the quiescent coronal magnetic field responsible for the appearance of large scale structures, namely structures that persist for at least a solar rotation - the phenomenological description of the fine scale structures within coronal mass ejections and eruptive prominences, and the subsequent large scale reconfigurations of ambient coronal structures - the inference of physical parameters characteristic of the quiescent and dynamic coronal structures. By mining the wealth of SoHO data spanning a full solar cycle, the proposed studies address key problems associated with the quiescent and dynamic manifestations of the coupled magnetic field and plasma system defining the solar corona. They are also bound to play a central role in the interpretation of future NASA missions, notably STEREO.

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**Fred Herrero / NASA Goddard Space Flight Center**
**A New Ion Spectrometer Instrument Concept for Near-Sun Orbit Missions Using Silicon Carbide Particle Detectors**

Summary We propose a new type of detector that enables a new instrument concept for solar wind ion energy spectrometers. The detector's expected energy threshold ranges from about 1 keV for protons to about 10 keV for iron. In a slow solar wind (200 km/s), these two ions have energies about 0.5 keV and 8 keV respectively. In our spectrometer concept, a planar accelerator grid with only 1 kilovolt accelerates H+ by 1 keV to 1.5 keV, and Fe+6 by 6 keV to about 14 keV - both energies well above the detector threshold. The key to the new spectrometer is therefore the SiC detector that enables the low voltage accelerator grid design. Our proposal describes how this detector will work, how we will build it, how it will discriminate against the visible and UV photon background and why it will be suitable for our principal goal to enable Solar Wind ion measurements in near-Sun orbits during quiet and disturbed solar conditions, as in the proposed LWS missions Solar Sentinels and Solar Probe and other future near-Sun missions. We exploit the Silicon Carbide (SiC) detector technology as developed at our laboratory. SiC detectors can operate at high temperatures (few 100°C), are radiation hard, mechanically and thermally robust, and with lower leakage currents than Si detectors. Furthermore, our new drift-APD detector will enable a new instrument concept with a dead layer only 8 nm thick for an energy threshold of about 1keV for protons and about 10 keV for Iron. Like Si, SiC is used to fabricate electronics directly on SiC wafers. Therefore, our SiC detectors will be fully integrated with amplifier/readout electronics on a single chip; thus avoiding the thermal expansion and mechanical problems associated with hybrid systems. Furthermore, the high temperature advantage of SiC with its low leakage current is realized throughout the entire detector-readout electronics system. We plan to develop our detector in two phases. The 1st phase provides a drift SiC detector with a dead layer of about 8 nm using a conventional output anode with amplifier gain that limits the minimum energy detected to 40 -

50 keV. The 2nd phase of the project adds an avalanche diode (APD) at the output to give us a drift-APD detector with the same small dead layer but with inherent multiplication gain in the APD adjustable from about 10^2 to 10^7. This level of gain will enable full use of the small dead layer feature to obtain threshold energies from 1 to 10 keV for protons and iron, respectively. The APD output is proportional to the input charge, making it possible to obtain a reliable energy scale in the drift-APD detector. Expected results will look like those in previous solar wind missions, except that the new data will be obtained near the Sun, as close as the LWS Sentinels and Solar Probe will go. SWICS and SWIMS data (ACE spacecraft) were used to estimate expected signal levels. Minimum and maximum expected fluxes show that a detector with sensitive area of 1 cm^2 will have count rates from roughly 10^2 to 10^7 per second, the latter being a bit high for a single detector to handle. Still, our detectors can handle these and higher count rates because they are micro-fabricated in modules of arrays of independent detectors. This makes it possible for the designer or mission PI to select and control dynamic range and sensitivity. This project will leverage on our current work on photodetectors and share on the use of test and fabrication facilities.

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**George Ho / Johns Hopkins University Applied Physics Laboratory**
**A High-temporal Resolution Suprathermal Ion Spectrometer Concept for Future Heliospheric (STISH) Missions**

Recent studies have revealed the importance of low-energy suprathermal particles (~10s of keV/q) in the heliosphere. They are found to contribute significantly as seed particles accelerated either close to the Sun during a solar energetic particle event, or locally at 1 AU during an energetic storm particle event. Traditionally these particles are measured using energy-per-charge (E/Q) and time-of-flight by energy (TOFxE) techniques. However, a spherical E/Q analyzer has the inherent difficulty in duty cycle; hence, high time resolution measurements of the suprathermal particles have never been made. Together with Southwest Research Institute, we propose to develop a new suprathermal ion spectrograph that measures energetic ions from 3 to 150 keV/q. The proposed instrument concept will use a new E/Q disperser design that allows us to cover the entire energy range in 5 voltage steps, thereby dramatically enhancing the duty cycle of the instrument (by a factor of 10). Two TOF sections (one with position sensitive anode) will be used to augment the E/Q measurement to resolve charge and element. This proposal fulfills one of the S3C strategic objectives: by designing, building, and validating the next generation of S3C instrumentation.

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**Charles Kankelborg / Montana State University**
**Probing the Sources of the High-Speed Solar Wind with the Multi-Order Solar EUV Spectrograph**

We propose to explore solar wind outflows in the upper transition region of the sun using simultaneous imaging spectroscopy. The existing MOSES sounding rocket payload will be refitted and flown to observe solar coronal holes in 465A Ne VII line. MOSES Observations of intensity, doppler shift and line width will allow the first spatially-resolved observations of the atmospheric dynamics generating waves that are believed to accelerate the high speed solar wind. As a prerequisite to the Ne VII observations, the lower transition region (He II 304A) data from the first MOSES flight (Feb 2006) will be analyzed. Simultaneous observations from SoHO/CDS will be compared with the spectra derived from MOSES. This work will establish the analysis techniques, capabilities and limitations of this novel imaging spectrometer.

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**Jakobus le Roux / University of California at Riverside**
**Time-Dependent Cosmic-Ray Acceleration and Propagation in the Termination Shock Region and Heliosheath**

This proposal addresses the Sun-Solar System Connection (SSSC) Science Objective to “Understand the fundamental physical processes of the space environment - from the Sun to Earth, to other planets, and beyond to the interstellar medium”, the SSSC Focus Area to “Understand the plasma processes that accelerate and transport particles”, and the SSSC Investigations “How are charged particles accelerated to high energies?” and “How are energized particles transported”. It is a non-flight Support and Research and Technology (SR&T) Solar and Heliospheric Physics (SHP) proposal that uses theory and modeling to investigate these issues in the outer heliosphere using Voyager observations as a constraint. More specifically, we plan to investigate the interesting unexpected time-dependent features of anomalous cosmic ray (ACR) spectra in the vicinity of the recently discovered heliospheric termination shock and in the heliosheath as observed with the Voyager 1 spacecraft. This will be achieved by using our various existing one and two dimensional time-dependent cosmic-ray and focused transport codes with complementing features, and linking them with a publicly available time-dependent MHD code used to model the time-dependent solar wind. With this set of codes the origin of the new termination shock particle component, the unexpected behavior of ACRs in the vicinity of the termination shock and in the heliosheath, such as the increase in the ACR intensity in the heliosheath, will be investigated using Voyager observations as a guide and a test for the simulations. Our first priority is to evaluate in unprecedented detail to what extent merged interaction regions are responsible for these features, while the role of solar wind flow geometry downstream in heating ACRs in the heliosheath, interstellar pickup ion preacceleration by strong compressive fluctuations downstream of the termination shock, and pickup ion preacceleration upstream in the inner heliosphere will also be analyzed. Studies such as these might revolutionize our understanding of interstellar pickup ion and ACR acceleration and transport at the termination shock, and in plasma sheath regions of our Sun, and of the many other stars that are similar to our Sun. Thus some of the consequences of interstellar neutral particle penetration into stellar winds will be illuminated.

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**Yuri Litvinenko / University of New Hampshire Space Science Center**
**Flare Energy Release and Particle Acceleration by Collisionless Magnetic Reconnection in the Solar Corona**

The principal role of magnetic reconnection in solar flares been confirmed using such satellites as Yohkoh, SOHO, and RHESSI. New observations impose strong constraints on theoretical models. We propose a three-year program of theoretical research that extends resistive MHD reconnection models by including collisionless effects. Our goal is to explain not only the overall energy release in flares but also the implications of collisionless reconnection for particle acceleration and energetics in coronal eruptions. We will employ a combination of analytical arguments and fluid and kinetic simulations. Among the numerical tools at our disposal are a magnetic reconnection code with adaptive mesh refinement, which integrates the Hall MHD equations in two and three dimensions, and an explicit particle-in-cell code that solves the collisionless coupled Vlasov-Maxwell system by the self-consistent integration of particle equations of motion and Maxwell's equations. We will compute the magnitude of the reconnection electric field as a function of the Lundquist number, electron and ion skin depths, and system size. We will derive the scaling laws that will allow us to extrapolate the results to the conditions in the solar corona. We will explore whether collisionless effects can lead to the observed sudden enhancement in solar energetic particles and how the spatial structure of the electric field influences the process of particle acceleration. We will investigate whether collisionless reconnection can explain and predict the energy release rates observed in solar flares. We will determine the spectra of accelerated particles from particle-in-cell simulations, scale the results to the conditions in the active solar corona, and compare the results with the particle and radiation fluxes observed in flares. The proposed research will help us to identify the simplest model that can describe the distributions of high-energy particles accelerated in the solar corona.

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**Dana Longcope / Montana State University**
**Quantitative Measurements of Magnetic Reconnection to and from Emerging Active Regions**

This is a proposal to develop a new method of measuring the flux transfer in reconnection events by quantifying the reconnection from a newly emerging active region (AR) to an existing AR nearby, using data from solar spacecraft. Sequences of EUV images are used to identify all the flux interconnecting the two regions over an extended period following emergence. The magnetic flux is quantified using a sequence of photospheric magnetograms made at cadences of one to two hours. The result is a time-resolved measurement of coronal flux interconnecting photospheric sources not previously connected. The time-rate of change of this flux is the electromotive force (EMF) maintained along the reconnection line (the separator). This method was pioneered by the investigators for the single case of the emergence of NOAA 9574 and its subsequent reconnection to 9570. In this case little reconnection occurred within the first 24 hours after flux emergence, followed by transfer of up to 1.0e17 Mx/sec (1.0e9 Volts of EMF). This flux transfer coincided with enhanced X-ray emission amounting to 1.0e31 ergs dissipated over three hours; quantitatively consistent with stress accumulated over 24 hours without reconnection. The proposed work would streamline the methodology used for 9574/9570, and then quantify reconnection in about 25 other emergences for which archival data exists from SoHO/MDI, TRACE and Yohkoh. The quantitative measurements of reconnection in this set of cases will statistically test the conclusions drawn on the basis of the single case already studied. The data will help confirm or contradict existing reconnection theories by answering questions such as, Does reconnection occur instantaneously or always after a delay? How does the rate of reconnection depend on the rate of driving? How does the amount of energy dissipated depend on the flux transfer and the length of delay? The method developed will permit the next generation of NASA-supported solar missions, including Solar-B and the Solar Dynamics Observatory, to make quantitative measurements of magnetic reconnection. Magnetic reconnection is the primary driver of coronal activity so a quantitative and predictive understanding of it is considered a critical element in the development of any Space Weather predictive capability. It is identified as a Critical Immediate Focus by NASA's Sun-Solar System Connection Science and Technology Roadmap}

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**Sergei Markovskii / University of New Hampshire**
**Numerical Simulations of the Turbulent Cascade in the Solar Wind at Kinetic Scales**

This project is aimed at understanding and describing quantitatively the dissipation of the turbulent fluctuations in the solar wind and the resulting ion heating. To this end, two contradictory pieces of evidence need to be reconciled. On the one hand, ions are observed to be heated across the magnetic field, which is usually a signature of the cyclotron damping of the turbulent fluctuations. On the other hand, MHD turbulent cascades are expected to produce fluctuations that are mostly low-frequency and highly oblique to the magnetic field, so that they cannot be cyclotron-resonant with the ions. To address this problem, the project team proposes a series of hybrid (fluid electrons and particle ions) numerical simulations of the turbulent cascade at the kinetic scales of frequencies and wavenumbers. At these scales, the cascade mechanism is likely to be modified. The investigators' preliminary analysis indicates that the ion cyclotron-resonant fluctuations can be generated in the kinetic range, in contrast with the MHD regime. The goal of the proposal is to verify this hypothesis, guided by a variety of data. The turbulence spectra and ion heating rates resulting from the simulations will be tested against observations from the Wind, ACE, and Helios spacecraft. The proposers have access to over 800 one-hour spectra reduced from ACE and Wind data. They have also extracted a typical perpendicular ion heating rate as a function of solar wind speed from the published Helios data, which will verify the numerical heating rates. The ion kinetics presumably plays a leading role in the cascade mechanism. Nevertheless, the heating of the electrons can extract a significant portion of the turbulent cascade energy. Therefore, the Landau damping of the turbulent fluctuations on the electrons has to be taken into account. Since that cannot be done in a hybrid code directly, a less detailed fluid description of the Landau damping will be employed. This approach will be sufficient for the purposes of this study because the details of the electron (unlike the ion) distribution functions in the solar wind will not be investigated. The obtained theoretical results will guide and enhance the observational capabilities of any present and future NASA missions designed to investigate the physical processes in the solar wind plasma, such as STEREO or Solar Orbiter. The solar wind is the conduit connecting the geospace and the solar active phenomena. It significantly affects the propagation of energetic particles and strong disturbances from the Sun to the Earth. Therefore, knowing the properties of the solar wind helps prevent the potential exposure of humans to harmful effects of the solar activity in the outer space. Thus, this work is important for the success of the future space exploration mapped out in the new national program of prolonged human activity on the Moon and on the roundtrip to Mars and supports the National Objective to extend the human presence across the Solar System. This proposal is centrally connected to ongoing efforts of the Theory Group at the University of New Hampshire. The group is led by eminent scientists and educators with a wide sphere of influence in the scientific community and the public at large. The interactions with the group members will help to engage and educate the public thus advancing the scientific and technological capabilities of the nation. By guiding and enhancing the observational capabilities of the space missions, this research will provide the information for policy formulation of federal agencies coordinating the national program of space exploration. Therefore, it will help to meet the National Objective to develop innovative technologies, knowledge, and infrastructures both to explore and to support decisions about the destinations for human exploration.

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**Pete Riley / Science Applications International Corporation**
**Understanding the Relationship between Coronal Mass Ejections and their Interplanetary Counterparts**

A fundamental scientific objective that pervades many of NASA's Space Science programs is to understand the heliospheric consequences of solar activity, and, in particular, coronal mass ejections (CMEs). We propose to apply sophisticated MHD models of CME initiation and evolution in the inner heliosphere, together with a novel new technique for tracing features in CMEs both forward and backward in time through the simulation to address several important issues concerning the relationship between CMEs observed at the Sun and their interplanetary counterparts. Specifically, we will investigate the following questions: - What is the "fate" of the 3-part structure of CMEs? Specifically, what is the relationship between the classic 3-part structure observed in coronal white light images and ICME signatures measured in interplanetary space? - What do composition measurements tell us about the source regions of CMEs? In particular, how do ACE and Ulysses in situ measurements relate to SoHO/UVCS measurements? - Why is the inferred helicity of ICMEs so different from the inferred helicity of the active regions associated with their eruption? - Do the models predict new and distinguishing signatures that can be searched for, either in solar and/or interplanetary datasets? Do their presence or absence constrain or even invalidate certain mechanisms? Our modeling will incorporate CME initiation via several promising mechanisms (such as flux cancellation and the "breakout" model) and our investigation will yield important constraints that must be addressed by the candidate mechanisms. We will simulate both idealized, generic events to study basic physical processes, as well as specific events (such as May 12th, 1997 and January 5th, 2005) to make direct comparisons with observations. The proposing team combines the required expertise in CME initiation, MHD modeling, and analysis of remote solar and interplanetary in situ observations. This work promises to shed important new insight on several important issues, yet the goals are focused, realistic, and attainable.

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**John Seely / Naval Research Laboratory**
**High-Reflectance Multilayer Coatings using Rare Earth Elements for Solar EUV Imaging Applications**

The determination of the optical constants and multilayer performance of rare earth elements will continue with the objective of developing optimized multilayer coatings that have high normal-incidence reflectance in the 45 nm to 70 nm wavelength range. The optical constants are determined from the transmittance and reflectance of thin films on silicon photodiode substrates measured using synchrotron radiation. Multilayers are deposited onto mirror substrates, and the reflectance is optimized for narrow-bandpass solar imaging applications. This work builds on the successful studies over the past three years of the optical constants and multilayer performance of La, Tb, Nd, and Gd. For example, promising narrowband SiC/Tb and Si/Tb multilayers, including B4C barrier layers, were developed with 23% peak reflectance at 60 nm. These types of multilayers can be adapted for imaging the O V 62.97 nm and Mg X 60.98 nm solar spectrum lines that originate primarily in the solar disk and coronal regions, respectively, and other spectral lines with a range of temperatures. These images can be used for determining the connectivity of solar regions with varying temperatures and structures. Among the remaining rare earth elements to be studied are Ce, Pr, Sm, Eu, Dy, Ho, Er, Tm, Yb, and Lu. All of these elements potentially have transmission windows in the 45-70 nm wavelength region.

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**George Withbroe / University of Minnesota**
**Sources of Solar Total Irradiance Variations**

Solar cycle variations in Total Solar Irradiance (TSI) have implications for both solar physics and for one of the most challenging long term environmental issues facing humanity, global warming. If we are to fully understand and predict the climatic effects of human modification of the terrestrial atmosphere and surface, we must fully understand the natural drivers of climate change. The most important of these is solar variability and the most widely accepted solar driver is variability of TSI. To fully understand and ultimately predict past and future variations in TSI, we need to improve our understanding of the sources of these variations. The proposed investigation uses measurements of photospheric intensities and magnetic fields obtained by the MDI instrument on SOHO to study the contribution of various types of solar features to variations of TSI. Also used are data from the VIRGO and SORCE total solar irradiance monitors and data from the LOI component of VIRGO. The goal is to determine the role of different solar features in generating variations of TSI over time scales of days to years and to improve our understanding of the cause(s) of the solar cycle variation of TSI. The investigation builds on results and techniques reported by Withbroe (Paper I, 2006, Solar Phys., in press). Paper I demonstrates that MDI data can be used to derive values of the mean irradiance from the solar disk whose temporal variations are in good agreement with corresponding precise measurements of TSI from VIRGO.

Paper I provides evidence that the quiet sun (regions with magnetic fields less than 10 gauss as measured by MDI) is a major contributor to the solar cycle variation of TSI. Many questions remain including: What feature or features cause(s) the solar cycle variation of the quiet sun irradiance? Is it the network? Is the global migration of elements from active region faculae the source of the quiet sun irradiance variations? Can we confirm with other data Paper I's finding that the irradiance from solar polar regions is brighter at solar maximum by 0.05% or more than at solar minimum? Do active region (sunspots and faculae) contributions to TSI cancel or nearly cancel on average over several solar rotations or less resulting in variations in the quiet sun irradiance being the primary source of longer term variations of TSI?

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**Martin Woodard / NorthWest Research Associates, Inc.**
**Probing Moderate-Scale Solar Subsurface Convection**

Probing Moderate-Scale Solar Subsurface Convection PROPOSAL SUMMARY The PI and Co-Is propose to extend and enhance an ongoing program of local helioseismic analysis to map supergranular-scale convection in the quiet Sun by 1) improving an existing wave-theory-based forward model used in the inversion of helioseismic data for subsurface flow, 2) evaluating the performance of inversion algorithms using artificial helioseismology data constructed for the purpose from numerical wave simulations, 3) implementing correlation-tracking methods to map photospheric flows, and 4) characterizing subsurface mesogranulation and the frequency-wavevector spectrum of supergranulation in detail from inversions of helioseismic data and correlation-tracking maps of photospheric flow. The detection and characterization of mesogranulation is a new direction for helioseismology and the proposed effort is expected to provide initial estimates of the pattern depth and therefore insight into the physical origin of mesogranulation. Further characterization of supergranular flow is designed to address issues, such as ?wave-like? behavior, which have arisen since the PI?s observational program began. The proposed and ongoing observational studies will use the existing database of helioseismology images from the MDI instrument on the NASA-sponsored SOHO spacecraft and the proposed theoretical developments will be part of the foundation for interpreting both MDI data and data from future space missions, such as the Solar Dynamics Observatory. The understanding of solar convection that will emerge from local helioseismic analysis will play an important role in unraveling the magnetohydrodynamics of the solar interior and the mechanism of solar variability and its effect on human activity.